

STATUS AND COMMISSIONING-RESULTS OF BESSY II*

R.J. Bakker** for the BESSY II Project Team***, BESSY, Berlin, Germany

Abstract

The new Storage Ring BESSY II in Berlin Germany is a dedicated third generation synchrotron radiation source for the VUV and soft X-ray spectral range [1]. On April 22nd, 1998 a 1.7 GeV electron beam was stored for the first time. Despite a relatively short time for commissioning of the synchrotron radiation source, the milestones were met as scheduled. Accelerator parameters that determine the quality of the synchrotron radiation are as designed or the design goals were even exceeded. The only parameter that is still not according to design is the beam lifetime, as the baking of the vacuum system is not completed yet. The regular scientific program started according to plan in January 1999 with experiments. The front-end for 22 additional beamlines are installed and scheduled for use before the end of next year. Thus required shutdown periods will also be used to install additional hardware to improve the performance of the ring.

1. TIME SCHEDULE

The BESSY II project was approved in 1992. At the end of 1996 the injector was assembled and the commissioning of the booster commenced [2]. On April 21st 1998, 3 months ahead of schedule, electrons were extracted out of the booster and injected into the main ring for the first time [3]. Already the next day beam storage and accumulation was achieved. Pilot user-experiments started on November 9 well before the beginning of the regular scientific program: January 11. For 1999 a three-mode schedule is planned with 9 weeks of beam-time for commissioning and machine studies, 20 weeks shut down to permit further installation of equipment, and 23 weeks of user-operation.

2. TECHNICAL DESCRIPTION

BESSY II employs a full energy injector that consists of a 70-kV DC thermionic gun, a 3 GHz racetrack microtron and a 10-Hz rapid-cycling synchrotron equipped with a

single 500 MHz rf-cavity [2]. The main ring has an extended double bend achromat lattice with 16-fold symmetry. Individually powered doublet- and triplet- focusing schemes around the dispersion-free straight sections allow for alternating high and low horizontal β -functions at the location of the insertion devices (ID's). Orbit correctors are incorporated in both the dipoles and in the 112 sextupoles. Four sextupoles also house skew quadrupoles for tuning of the global coupling.

Up to 14 straight are suited for installation of ID's of which 5 are installed: a 4-T super-conducting wavelength shifter, a 180 mm period electromagnetic undulator, and 3 hybrid undulators with variable gap (two planar polarized with a period of 49 and 125 mm, respectively, and one elliptically polarized with a period of 56 mm). The remaining straight sections are used for the rf-system and the injection [4], respectively. The former is located in one of the low- β sections and consists of four DORIS type 500 MHz single-cell cavities, fed with 75 kW DC klystron each.

Table 1. Main specifications of BESSY II

Parameter		Design	Achieved	
Energy	E	0.9-1.9	0.85-1.9	GeV
Acceptance (rms)	$\Delta E/E$	± 3	-3 / +5	%
Current	I	100	397	mA
Tune	Q_x	17.8	17.85	
	Q_y	6.7	6.72	
Nat. Chromaticity	ξ_x	-48		
	ξ_y	-23		
Max dispersion	η_x	0.44	0.42	m
Emittance ^{*)}	ϵ_x	6	6	nm rad
Coupling	c	<3	<0.1	%
Comp. factor [4]	α	7.3×10^{-4}	7.3×10^{-4}	
Life time ^{**)}	τ	>6	3.4	h
Injection rate	I_{inj}	6	6	mA/s

^{*)} $E = 1.7$ GeV, ^{**)} $I = 100$ mA

The booster governs the filling of the ring. In the default mode the injection is synchronized with the 10 Hz of the booster and a bunch-train of 120 buckets out of the possible 400 are filled. It is also possible to fill in a toggled mode and in an asynchronous mode where the bunch-trains are injected at two different locations or at fully random position, respectively. Single bunch operation is presently in preparation and planned for the near future.

The performance of the ring is summarized in Tab. 1. A more complete description of the installed hardware can be found in Ref. 3.

3. COMMISSIONING RESULTS

After the beam was stored in the main ring for the first time [3] a commissioning program started which aimed

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** email: bakker@bii.bessy.de

*** W. Anders, R. Bakker, B. Bauda, T. Becker, T. Birke, K. Buerkmann, B. Dittmann, V. Dür, D. Faulbaum, J. Feikes, W. Gericke, M. von Hartrott, H.G. Hoberg, E. Jaeschke, S. Khan, J. Kolbe, D. Krämer, S. Kühler, B. Kuner, B. Kuske, P. Kuske, T. Knuth, R. Lange, K. Ludwig, B. Martin, M. Martin, I. Mueller, R. Müller, K. Ott, H. Prange, F. Radecke, D. Richter, H. Rüdiger, T. Schneegans, D. Simmering, U. Strönisch, S. Vogt, E. Weihreter, T. Westphal, G. Wüstefeld

for stable operation conditions according to the design parameters as quickly as possible. During commissioning the mayor setback encountered was related to the vacuum system: two fine whiskers in the ring vacuum vessel caused unstable injection conditions. It took until the end of August before the reasons were clear and the cause of the troubles could be localized and removed. Non the less it was possible to reach the goal and a solid basic understanding of the machine is obtained. Below follows a collection of some of the results.

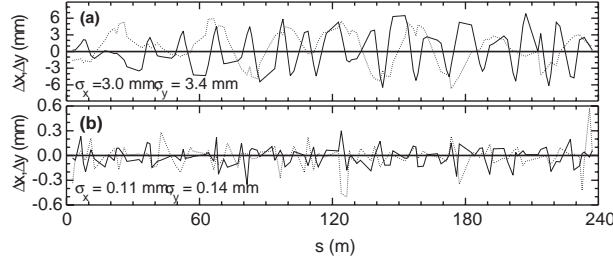


Figure 1 Original horizontal (solid line) and vertical (dotted line) closed orbit (a) compared with the present orbit (b).

3.1 Beam Optics

The beam position monitor system (bpm) [6] was already available on the first day of commissioning. The initial orbit showed large excursions in both planes, see Fig. 1a. Furthermore, the vertical tune appeared to be one unit smaller than the design tune. Both errors were adjusted with the aid of available orbit-correction algorithms [7,8] based on the closed orbit response on both corrector variations and quadrupole variations. For this, a good understanding of the linear lattice is essential and the ring was operated with sextupoles off for some time, i.e., with extremely negative natural chromaticities. As this mode causes the machine to be extremely sensitive with very short beam lifetimes, it was due to the patience and hard work of the crew that this mode of operation could be obtained. The orbit in Fig. 1b is the present one relative to the ‘natural’ machine orbit, i.e., the orbit that has minimal distortion on variations of the quadrupole fields [6].

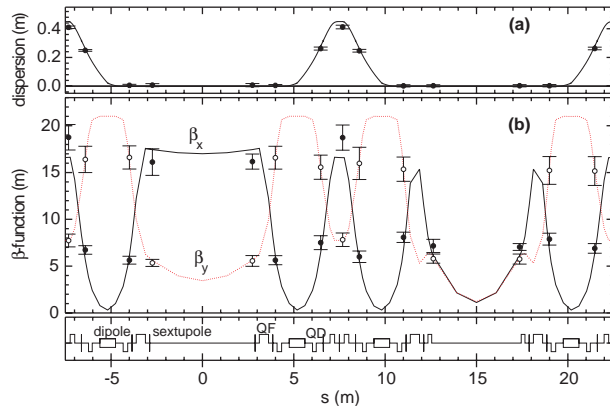


Figure 2 Comparison of the design twiss-parameters (solid curve) with the result of orbit corrector response measurements. The error bars indicate the rms variation of the parameters between the 8 sections of the ring.

The machine parameters shown in Fig. 2 depict the present understanding. The β -beating along the ring has been reduced to below 10 %.

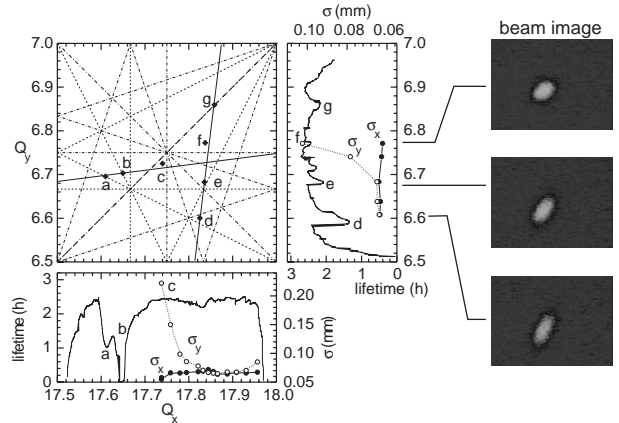


Figure 3 Lifetime and transverse beam-size as a function of the tune. The solid lines mark the path of recording through the resonance diagram. Visible resonance-crossings are labeled.

3.2 Tune dependency

Around the design tune ($Q_x=17.8$, $Q_y=6.7$) the resonance diagram was scanned to find optimum operational conditions in terms of lifetime and optical spot-size. The former was recorded with the standard current monitor available whereas the latter was obtained from an imaging system on a dipole beamline. Fig. 3 shows an example of some of the results obtained [9]. The present working point ($Q_x=17.85$, $Q_y=6.72$) is a combined optimum of stable lifetime conditions (the absence resonance lines that deteriorate the lifetime) and small optical spot-size.

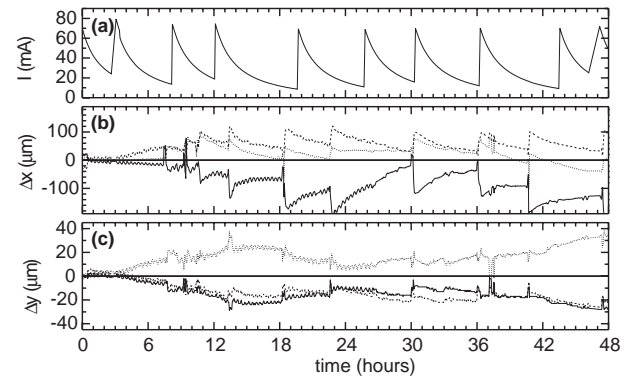


Figure 4 Typical machine performance without orbit correction, recorded on Nov. 24 and 25, 1998: (a) beam intensity, horizontal (b) and vertical (c) orbit stability recorded at 3 different positions in one sector.

3.3 Orbit Stability

The ring is equipped with 112 bpm pickup stations that can track both fast (up to single turn) and slow orbit changes [6]. In a standard mode of operation the bpm’s record a closed orbit with 1 Hz and an accuracy of 1 μ m. Typical log-data during a user-ring is shown in Fig. 4.

Without any correction the current-dependent drifts are of the order of 5 μm in the vertical, and 40 μm in the horizontal plane during the time in which the current drops from 100 to 40 mA. On a larger time-scale drifts add up to 40 μm and 150 μm , respectively. Orbit distortions are increased due to external influences such as variation of undulator gaps: e.g., the orbit distortion at $t = 37.5$ h in Fig. 4. The oscillations that disappear after $t = 27$ h could be traced back to fluctuations in the cooling water temperature on a sub degree scale.

Until now user operation has been performed in a mode as described above. However, initial tests with a slow feedback system [7] indicate that it is possible to significantly reduce these drifts and to compensate for sources of distortion. Present studies aim to minimize the correction without sacrificing the achievable orbit definition.

3.4 Beam lifetime and Vacuum

The beam lifetime is still dominated by the vacuum pressure. Until the end of 1998 only 1/3 of the ring was baked. The influence of the vacuum was intensified because the vacuum system needed to be opened on several occasions for completing machine elements and user front-ends. Consequently, desorption by the photon beam is still the dominant process in reducing the vacuum pressure and lifetime [10]. Fig. 5 displays the lifetime at 20 and 100 mA. Resets of the integrated dose curve correspond with moments on which the vacuum was broken. Note that the graph displays logged lifetime data. Hence, reduction may also be caused by non-lifetime optimized machine studies that took place at the time of logging. It is anticipated that the lifetime will increase as the vacuum improves.

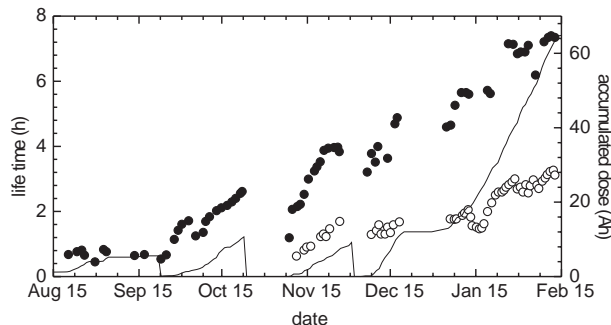


Figure 5 Lifetime at 20 mA (solid dots) and 100 mA (open dots) of beam current and accumulated dose (curve) versus time.

4. OPERATIONAL STATISTICS

From April 1998 until February 1999 a total of 2540 hours of beam time have been recorded of which 1850 hours were used for machine studies and optimization. The rest was used for the regular scientific program, which accumulated the most hours during the last 5 weeks of operation (460 hours).

During the initial nine months less than 300 hours had to be counted as downtime. Hence, already during commissioning the reliability of the machine proved to be better

than 80%. The most time consuming reasons for the downtimes were: a) an insufficient cooling of a coil in a transfer-line magnet which got damaged, and b) the two tiny fine whiskers mentioned before. No significant hardware failures were reported while commissioning and during the 5 weeks of user operation no downtime has been recorded at all.

5. FUTURE PLANS

Further development of BESSY II takes place on several fronts simultaneously. First more ID's will be installed and more beamlines will be built up, e.g., a 7-T wavelength shifter build by BINP/Novosibirsk. From the machine side more hardware will be installed to make operation more stable and versatile. For this year a new electron gun will come available that enables single bunch operation. Also several feedback systems are anticipated to boost the performance in the imminent future [11,12]. In collaboration with MAX-Lab/Lund, attention is focuses on the installation of 3rd harmonic cavities.

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